Student Textbook pages 724–727

Answers to Understanding Concepts Questions

Understanding Concepts

1. A system like this is not at equilibrium because it is not a closed system.
2. **(a)** heterogeneous
   (b) homogeneous
   (c) homogeneous
   (d) heterogeneous
   (e) heterogeneous
3. **(a)** heterogeneous
   (b) heterogeneous
   (c) heterogeneous
   (d) heterogeneous
4. **(a)** $K_c = \dfrac{[H_2(g)]^3[CO(g)]}{[CH_4(g)][H_2O(g)]}$

   (b) $K_c = \dfrac{[NO(g)]^4}{[N_2O(g)]^2[O_2(g)]}$

   (c) $K_c = \dfrac{[POCl_3(g)]^2}{[PCl_3(g)]^2[O_2(g)]}$

   (d) $K_c = \dfrac{[N_2(g)][H_2O(g)]^2}{[NO(g)]^2[H_2(g)]^2}$

   (e) $K_c = \dfrac{[C_7H_8(g)][H_2(g)]^3}{[C_7H_{14}(g)]}$
5. Reactions (c) and (d) will shift to the right to re-establish equilibrium if the volume of the container is decreased.

6. Reaction (a) will shift to the left to re-establish equilibrium if the temperature of the system is decreased.

7. **(a)** Reactants are favoured when the temperature is increased.

(b) No change occurs when helium gas is added at constant volume.

(c) Reactants are favoured when helium gas is added at constant pressure.

8. Helium does not react with any gases in the equation, and adding He(g) at constant volume leaves the concentration of reacting gases unchanged. Therefore, the equilibrium is not affected.

9. **(a)** Removing $O_2(g)$ will cause the reaction to shift to the left to re-establish equilibrium.

(b) Adding NO(g) will cause the reaction to shift to the left.

(c) Adding $H_2O(g)$ will cause the reaction to shift to the left.

(d) Adding a catalyst will have no effect on the position of equilibrium.

(e) Decreasing the volume of the container will cause the reaction to shift to the left.

(f) Cooling the container will cause the reaction to shift to the right.

10. The reaction shifts to the right at the higher temperature. Based on this information only, Le Châtelier's principle predicts the reaction is endothermic.

11. **(a)** The statement is false. The equilibrium constant does depend on temperature.

(b) The statement is false. The rate of a reaction does not depend on the magnitude of the equilibrium constant.

(c) The statement is false. At equilibrium, the concentration of reactants and the concentration of products are determined by the stoichiometry and the equilibrium constant for the reaction.

(d) The statement is false. The equilibrium constant is a ratio of product concentrations to reactant concentrations.

12. The position of equilibrium lies to the right at lower temperature. Although this increases the yield of product, the rate is slower at lower temperatures. A compromise is made between a good rate and reasonable yield.

13. Syngas is a mixture of carbon monoxide and hydrogen gas. Syngas can be produced by reacting methane with steam:

$$CH_4(g) + H_2O(g) + \text{heat} \rightleftharpoons CO(g) + 3H_2(g)$$

By adjusting the temperature and pressure conditions, different proportions of the reacting gases will be present at equilibrium.

14. The most important gases responsible for acid deposition are $SO_2(g)$, $SO_3(g)$, $NO(g)$ and $NO_2(g)$.

15. In Alberta, the pollutants that cause acid rain come mainly from removing sulfur from natural gas and oil, and from power plants that burn coal containing sulfur compounds.

16. The conjugate acids are:

(a) $H_2SO_4(aq)$, sulfuric acid

(b) $NH_4^+(aq)$, ammonium ion

(c) $H_3O^+(aq)$, hydronium ion

(d) $H_2PO_4^-(aq)$, dihydrogen phophate ion

17. The conjugate bases are:

(a) $SO_4^{2-}(aq)$, sulfate ion

(b) $NO_2^-(aq)$, nitrite ion

(c) $HSO_3^-(aq)$, hydrogen sulfite ion.

(d) $O^{2-}(aq)$, oxide ion

18. The conjugate acid-base pairs are: $HClO_2(aq)/ClO_2^-(aq)$ and $H_2O(\ell)/H_3O^+(aq)$.

19. The conjugate acid-base pairs are: $HBO_3^{2-}(aq)/H_2BO_3^-(aq)$ and $HSIO_3^-(aq)/SIO_3^{2-}(aq)$

20. (a) $K_a = \dfrac{[H_3O^+(aq)][CN^-(aq)]}{[HCN(aq)]}$

(b) $K_a = \dfrac{[H_3O^+(aq)][HPO_4^{2-}(aq)]}{[H_2PO_4^-(aq)]}$

(c) $K_a = \dfrac{[H_3O^+(aq)][HCOO^-(aq)]}{[HCOOH(aq)]}$

(d) $K_a = \dfrac{[H_3O^+(aq)][OOCCOO^{2-}(aq)]}{[HOOCCOO^-(aq)]}$

21. (a) $K_b = \dfrac{[HF(aq)][OH^-(aq)]}{[F^-(aq)]}$

(b) $K_b = \dfrac{[H_2C_6H_6O_6(aq)][OH^-(aq)]}{[HC_6H_6O_6^-(aq)]}$

(c) $K_b = \dfrac{[N_2H_5^+(aq)][OH^-(aq)]}{[N_2H_4(aq)]}$

(d) $K_b = \dfrac{[PH_4^+(aq)][OH^-(aq)]}{[PH_3(aq)]}$

22. $CH_3COOH(aq) < H_3PO_4(aq) < HF(aq) < HI(aq)$.

23. $I^-(aq) < F^-(aq) < H_2PO_4^-(aq) < CH_3COO^-(aq)$

24. (c) is a buffer, because the solution will contain $NH_3(aq)$ and $NH_4^+(aq)$. The other solutions are not buffers.

25. (a) Possible answers include $NH_4^+(aq)/NH_3(aq)$ and $CH_3COOH(aq)/CH_3COO^-(aq)$

(b) Possible answers include $HCl(aq)/Cl^-(aq)$ and $HNO_3(aq)/NO_3^-(aq)$

Answers to Applying Concepts Questions

26. The percentage of sulfur dioxide that reacts at this temperature is relatively large. Twice as much sulfur dioxide reacts compared with the percentage of $O_2(g)$ that reacts.

27. The ICE table is:

concentration (mol/L)

$$I_2(aq) + I^-(aq) \rightleftharpoons I_3^-(aq)$$

Initial	0.002	0.002	0
Change	$-x$	$-x$	$+x$
Equilibrium	5.0×10^{-4}	$0.002 - x$	x

$0.002 - x = 5.0 \times 10^{-4}$

$x = 0.0015$

At equilibrium, $[I_2(aq)] = 5.0 \times 10^{-4}$ mol/L; $[I^-(aq)] = 5.0 \times 10^{-4}$ mol/L; $[I_3^-(aq)] = 0.0015$ mol/L

$$K_c = \frac{[I_3^-(aq)]}{[I_2(aq)][I^-(aq)]} = \frac{0.0015}{(5.0 \times 10^{-4})(5.0 \times 10^{-4})}$$

$K_c = 6 \times 10^3$

28. Initial concentrations:

$$[H_2(g)] = \frac{3.60}{2.00} = 1.80 \text{ mol/L}$$

$$[CO_2(g)] = \frac{5.20}{2.00} = 2.60 \text{ mol/L}$$

The ICE table is:

concentration (mol/L)

$$H_2(g) + CO_2(g) \rightleftharpoons H_2O(g) + CO(g)$$

Initial	1.80	2.60	0.00	0.00
Change	$-x$	$-x$	$+x$	$+x$
Equilibrium	$1.80 - x$	$2.60 - x$	x	x

75% of $H_2(g)$ reacts $= 0.75 \times 1.80 = 1.35$ mol/L $= x$

Equilibrium concentrations:

$[H_2(g)] = (1.80 - 1.35) = 0.45$ mol/L

$[CO_2(g)] = (2.60 - 1.35) = 1.25$ mol/L

$[H_2O(g)] = 1.35$ mol/L

$[CO(g)] = 1.35$ mol/L

$$K_c = \frac{[H_2O(g)][CO(g)]}{[H_2(g)][CO_2(g)]} = \frac{(1.35)(1.35)}{(0.45)(1.25)}$$

$K_c = 3.2$

29. Let the initial concentration of reactant gases be 1.00 mol/L. The change in concentration of $N_2(g)$ at equilibrium is $0.053 \times 1.00 = 0.053$ mol/L.

ICE table:

concentration (mol/L)

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

Initial	1.00	1.00	0
Change	−0.053	−0.053	+0.106
Equilibrium	0.947	0.947	0.106

$$K_c = \frac{[NO(g)]^2}{[N_2(g)][O_2(g)]} = \frac{(0.106)^2}{(0.947)(0.947)}$$

$K_c = 1.3 \times 10^{-2}$

30. Initial concentration:

$$[NO_2(g)] = \frac{0.100}{4.00} = 0.0250 \text{ mol/L}$$

ICE table:

concentration (mol/L) $2NO_2(g) \rightleftharpoons N_2O_4(g)$

Initial	0.0250	0
Change	$-2x$	$+x$
Equilibrium	$0.0250 - 2x$	x

74% of $NO_2(g)$ reacts $= 0.74 \times 0.0250 = 0.0185$ mol/L
$= 2x$

Equilibrium concentrations:

$[NO_2(g)] = (0.0250 - 0.0185) = 0.0065$ mol/L

$[N_2O_4(g)] = 0.0092$ mol/L

$$K_c = \frac{[N_2O_4(g)]}{[NO_2(g)]^2} = \frac{0.0092}{(0.0065)^2}$$

$K_c = 2.2 \times 10^2$

31. (a) ICE table:

concentration (mol/L)

$HOCl(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + OCl^-(aq)$

Initial	0.065		≈ 0	0
Change	$-x$		$+x$	$+x$
Equilibrium	$0.065 - x$		x	x

$$\frac{[HOCl(aq)]}{K_a} = \frac{0.065}{4.0 \times 10^{-8}} >> 1000$$

Therefore, at equilibrium, $[HOCl(aq)] \approx 0.065$ mol/L

$$K_a = \frac{[H_3O^+(aq)][OCl^-(aq)]}{[HOCl(aq)]}$$

$$4.0 \times 10^{-8} = \frac{x^2}{0.065}$$

$$x = [H_3O^+(aq)] = 5.10 \times 10^{-5} \text{ mol/L}$$

$$\text{pH} = -\log[H_3O^+(aq)] = 4.29$$

$$\text{percent ionization} = \frac{5.0 \times 10^{-5}}{0.065} \times 100 = 0.077\%$$

(b) The conjugate base of HOCl(aq) is $OCl^-(aq)$.

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{4.0 \times 10^{-8}}$$

$$K_b = 2.5 \times 10^{-7}$$

32. The amount that ionizes is
$0.25 \times 0.030 = 0.0075$ mol/L.

ICE table:

concentration (mol/L)

$$HA(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + A^-(aq)$$

Initial	0.25		≈ 0	0
Change	–0.0075		+ 0.0075	+ 0.0075
Equilibrium	0.25 – 0.0075 = 0.242		0.0075	0.0075

$$[H_3O^+(aq)] = 0.0075 \text{ mol/L}$$

$$\text{pH} = -\log[H_3O^+(aq)] = -\log(0.0075)$$

$$\text{pH} = 2.12$$

$$\text{pOH} = 14.00 - \text{pH} = 11.88$$

$$[OH^-(aq)] = 10^{-\text{pOH}} = 10^{-11.88}$$

$$[OH^-(aq)] = 1.3 \times 10^{-12} \text{ mol/L}$$

$$K_a = \frac{[H_3O^+][A^-(aq)]}{[HA(aq)]} = \frac{(0.0075)(0.0075)}{0.242}$$

$$K_a = 2.3 \times 10^{-4}$$

33. The conjugate acid of $HSeO_3^-(aq)$ is $H_2SeO_3(aq)$.

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{3.5 \times 10^{-3}}$$

K_b for $HSeO_3^-(aq) = 2.9 \times 10^{-12}$

34. (a) $$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{6.2 \times 10^{-10}}$$

K_b for $CN^-(aq) = 1.6 \times 10^{-5}$

(b) ICE table:

concentration (mol/L)

$$HCN(aq) + H_2O(\ell) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$$

Initial	0.12		≈ 0	0
Change	$-x$		$+x$	$+x$
Equilibrium	$0.12 - x$		x	x

$$\frac{[HCN(aq)]}{K_a} = \frac{0.12}{6.2 \times 10^{-10}} >> 1000$$

Therefore, at equilibrium, $[HCN(aq)] \approx 0.12$ mol/L

$$K_a = \frac{[H_3O^+(aq)][CN^-(aq)]}{[HCN(aq)]}$$

$$6.2 \times 10^{-10} = \frac{x^2}{0.12}$$

$x = 8.63 \times 10^{-6}$ mol/L $= [H_3O^+(aq)]$

$pH = -\log(8.63 \times 10^{-6}) = 5.06$

35.

$$C_6H_5COOH(aq) + H_2O(\ell) \rightleftharpoons C_6H_5COO^-(aq) + H_3O^+(aq)$$

	$[C_6H_5COOH(aq)]$ (mol/L)	$[H2O(\ell)]$ (mol/L)	$[C_6H_5COO^-(aq)]$ (mol/L)	$[H_3O^+(aq)]$ (mol/L)
Initial	0.25		0	0
Change	–x		+x	+x
Equilibrium	0.25–x		+x	+x

$$\frac{[C_6H_5COOH]}{K_a} = \frac{0.25}{6.3 \times 10^{-4}}$$

$$= 4.0 \times 10^2$$

Since this value is less than 1000, the amount that ionizes is significant compared with the initial concentration of acid. Therefore, the approximation cannot be used. The value for x must be determined using either the quadratic equation or a graphing calculator.

$$K_a = \frac{[C_6H_5COO^-][H_3O^+]}{[C_6H_5COOH]}$$

$$6.3 \times 10^{-4} = \frac{(x)(x)}{(0.25 - x)}$$

$$6.3 \times 10^{-4}(0.25 - x) = x^2$$

$$0 = x^2 + 6.3 \times 10^{-4}x - 1.6 \times 10^{-4}$$

$$x = 0.012 \text{ or } 0.013$$

Only the positive root is possible, therefore $[H_3O^+(aq)] = 0.012$ mol/L

$$\text{Percent Ionization} = \frac{0.012 \text{ mol/L}}{0.25 \text{ mol/L}} \times 100\%$$

$$= 4.8\%$$

36. ICE table:

concentration (mol/L)

$$BH(aq) + H_2O(\ell) \rightleftharpoons OH^-(aq) + BH_2^+(aq)$$

Initial	0.16		≈ 0	0
Change	$-x$		$+x$	$+x$
Equilibrium	$0.16 - x$		x	x

$$\frac{[BH(aq)]}{K_b} = \frac{0.16}{1.55 \times 10^{-4}} > 1000$$

Therefore, at equilibrium, $[BH(aq)] \approx 0.16$ mol/L

$$K_b = \frac{[BH_2^+(aq)][OH^-(aq)]}{[BH(aq)]}$$

$$1.55 \times 10^{-4} = \frac{x^2}{0.16}$$

$x = 4.98 \times 10^{-3}$ mol/L $= [OH^-(aq)]$

$pOH = -\log[OH^-(aq)] = -\log(4.98 \times 10^{-3}) = 2.303$

$pH = 14.00 - pOH = 14.00 - 2.303$

$pH = 11.70$

37. $H_2S(aq)$ is a stronger acid than $HCN(aq)$, because an acid-base reaction always proceeds from the stronger to the weaker acid.

38. (a) $CH_3COOH(aq)$ is a stronger acid than $H_2S(aq)$. Therefore, the equilibrium mixture favours reactants.

(b) $NH_4^+(aq)$ is a stronger acid than $HCO_3^-(aq)$. Therefore, the equilibrium mixture favours products.

(c) $HSO_4^-(aq)$ is a stronger acid than $HCN(aq)$. Therefore, the equilibrium mixture favours reactants.

(d) $H_2CO_3(aq)$ is a stronger acid than $HCN(aq)$. Therefore, the equilibrium mixture favours products.

39. (a) 1, 2, 6, and 8 would definitely allow the student to solve the problem.

- Method 1 – a weak acid will have a higher pH than the expected pH of 1.0 if the acid were strong.

- Method 2 – the equivalence point will be at pH 7 if the acid is strong, above pH 7 if the acid is weak.
- Method 3 – although a strong acid will react more vigorously than a weak acid, without a comparison, the student will not be able to tell if the reaction is "more" or "less" vigorous.
- Method 4 – since the number of moles of hydrogen atoms is the same in a weak or strong acid with the same concentration, the same volume of gas will be generated regardless of whether the unknown is weak or strong.
- Method 5 – since the number of moles of hydrogen atoms is the same in a weak or strong acid with the same concentration, the same amount of energy will be released during the neutralization reaction.
- Method 6 – the final pH of the mixture will be 7 if the acid is a strong acid (the pH at neutralization for a strong acid/strong base), the pH will be greater than 7 if the acid is a weak acid (the pH at neutralization for a weak acid/strong base)
- Method 7 – although the voltage will be slightly lower for a weak acid than a strong acid (since the concentration of the hydrogen ions is lower), without a strong acid cell for comparison, the student will not be able to identify the acid.
- Method 8 – the acid will react at the same vigor as the HCl(aq) if it is a strong acid. If it is a weak acid, it will react more slowly.

(b) Method 1

- sample of acid
- beaker
- pH paper or pH meter

Method 2

- sample of acid
- 0.100 mol/L NaOH(aq) solution
- pH paper or pH meter
- distilled water
- pipette
- burette and burette clamp
- retort stand
- funnel
- pipette bulb
- Erlenmeyer flask

Method 6

- sample of acid
- graduated cylinder(s)
- 0.10 mol/L NaOH(aq)
- 100 mL beaker
- stirring rod
- pH paper or pH meter

Method 8

- sample of acid
- balance
- $NaHCO_3(s)$
- 0.100 mol/L HCl(aq)
- stopwatch
- 100 mL beaker(s)
- stirring rod

(c) The titration of 10.0 mL of 0.100 mol/L solution of an unknown acid with 0.100 mol/L NaOH(aq)

Volume of NaOH(aq) added (mL)	pH
0.00	
1.00	
2.00	
3.00	
4.00	
5.00	

Volume of NaOH(aq) added (mL)	pH
6.00	
7.00	
8.00	
9.00	
10.00	
11.00	
12.00	
13.00	
14.00	
15.00	

(d) The important controlled (or fixed) variables are: the mass of $NaHCO_3(s)$, the volume of the acid used, the concentration of the acid used.

(e) If the unknown acid is a strong acid, its pH will be 1.000. ($pH = -\log[H_3O^+(aq)] = -\log(0.100) = 1.000$)

(f) $Zn(s) + 2H_3O^+(aq) \rightarrow H_2(g) + Zn^{2+}(aq) + 2H_2O(\ell)$ or $Zn(s) + 2H^+(aq) \rightarrow H_2(g) + Zn^{2+}(aq)$

(g) If the acid solution had a concentration of 1.00 mol/L, the predicted voltage would be 0.45 V. Since the concentration is only 0.100 mol/L, the voltage would likely be less.

Answers to Solving Problems Questions

40. Accept reasonable estimates, with supporting calculations. The sources used should be correctly referenced. Information about coal may be found on an Alberta government site at:
http://www.energy.gov.ab.ca/436.asp

According to information on this site, the sulfur content in the coal from Alberta mines is typically less than 0.5%.

Natural Resources Canada has information about coal based electrical generation at:
http://www.nrcan.gc.ca/es/etb/cetc/combustion/cctrm/htmldocs/map_electrical_utility_e.html

From this site, students can find further information. For example, about the Keephills generating plants in the Wabamun Lake area of Alberta:
http://www.transalta.com/website2001/tawebsite.nsf/AllDoc/1C13A445807845A4872569AE00737AF8?OpenDocument
The plants at Keephills consume 3.2 million tonnes of coal annually. The mass of sulfur burned is therefore approximately $0.005 \times 3.2 \times 10^6$ t $= 1.6 \times 10^4$ t. This produces a mass of $SO_2(g)$:

$$1.6 \times 10^4 \times \frac{64}{32} = 3.2 \times 10^4 \text{ t.}$$

Sulfur dioxide gas can be removed in wet or dry scrubber towers to form sulfates that can be produced into by-products such as gypsum. Spraying the emission gases with ammonia removes $NO_x(g)$ as ammonium nitrate, and $SO_2(g)$ as ammonium sulfate.

41. (a) Acidic deposition is linked to sulfurous acid, $H_2SO_3(aq)$, sulfuric acid, $H_2SO_4(aq)$, nitrous acid, $HNO_2(aq)$, nitric acid, $HNO_3(aq)$.

(b) $SO_2(g) + H_2O(\ell) \rightleftharpoons H_2SO_3(aq)$

$SO3(g) + H2O(\ell) \rightleftharpoons H_2SO_4(aq)$

$2NO_2(g) + H_2O(\ell) \rightleftharpoons HNO_2(aq) + HNO_3(aq)$

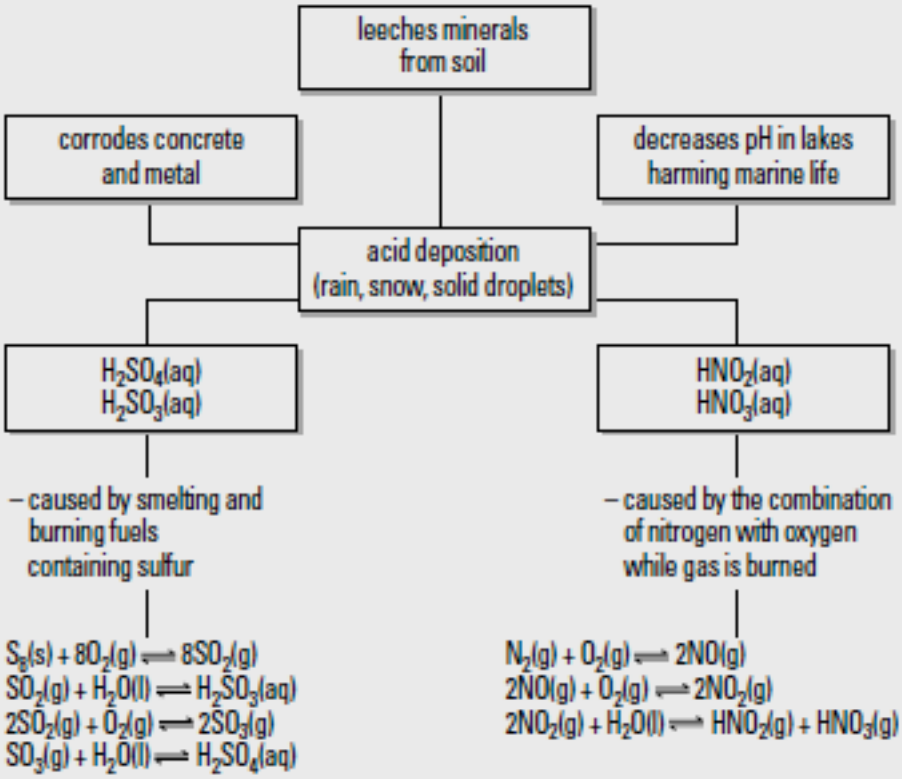
(c) $SO_x(g)$: the burning of fuels containing sulfur (especially coal), the smelting of ores (purifying metals), the removal of sulfur from natural gas and oil

$NO_x(g)$: as a byproduct in the burning of gasoline

(d) The effects of acidic deposition include:

- destruction of trees and other forms of land life
- leeching of minerals from the soil which can be toxic to marine life
- decreased pH in bodies of water leading to the death of marine life
- erosion of concrete structures
- increased rate of corrosion of metal

(e)


leeches minerals from soil
corrodes concrete and metal
decreases pH in lakes harming marine life
acid deposition (rain, snow, solid droplets)
$H_2SO_4(aq)$ $H_2SO_3(aq)$
$HNO_2(aq)$ $HNO_3(aq)$
– caused by smelting and burning fuels containing sulfur
– caused by the combination of nitrogen with oxygen while gas is burned
$S_8(s) + 8O_2(g) \rightleftharpoons 8SO_2(g)$
$SO_2(g) + H_2O(l) \rightleftharpoons H_2SO_3(aq)$
$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$
$SO_3(g) + H_2O(l) \rightleftharpoons H_2SO_4(aq)$
$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$
$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$
$2NO_2(g) + H_2O(l) \rightleftharpoons HNO_2(g) + HNO_3(g)$

42. An amphiprotic substance can act either as a proton donor or a proton acceptor. The hydrogen carbonate ion is a good example. As a proton donor:

$$HCO_3^-(aq) + OH^-(aq) \rightleftharpoons CO_3^{2-}(aq) + H_2O(\ell)$$

As a proton acceptor:

$$HCO_3^-(aq) + H_3O^+(aq) \rightleftharpoons H_2CO_3(aq) + H_2O(\ell)$$

43. $HNO_2(aq) + OH^-(aq) \rightleftharpoons NO_2^-(aq) + H_2O(\ell)$

$NO_2^-(aq) + H_3O^+(aq) \rightleftharpoons HNO_2(aq) + H_2O(\ell)$

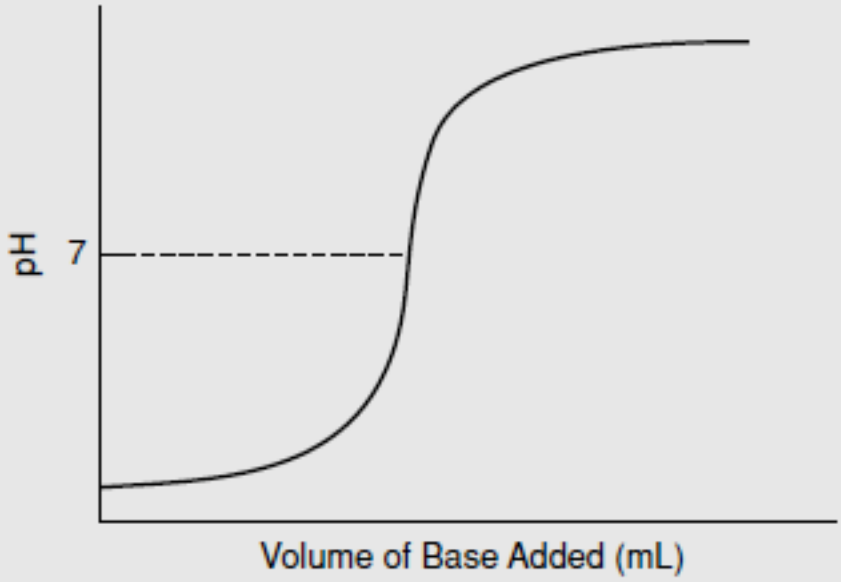
44. The endpoint in a titration is the point at which an indicator changes colour. The equivalence point in an acid-base titration is the point at which the number of moles of acid is equal to the number of moles of base. The equivalence point may occur before, after, or coincide with the endpoint, depending on the choice of indicator for a particular titration.

(a) The titration of a strong acid with a weak base will form an aqueous solution with pH < 7 at equivalence. An indicator that changes colour in the acidic range should be chosen.

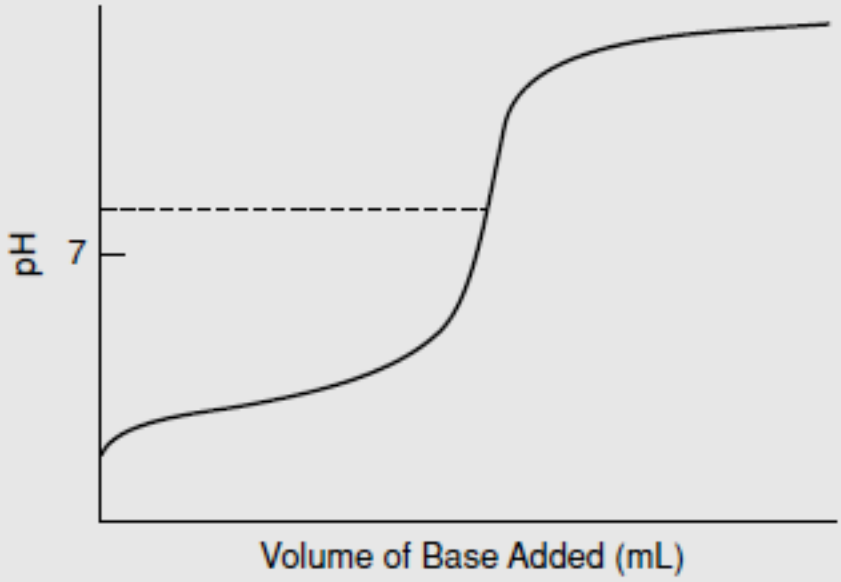
(b) A different indicator should be chosen in this case, because the solution will be basic at equivalence.

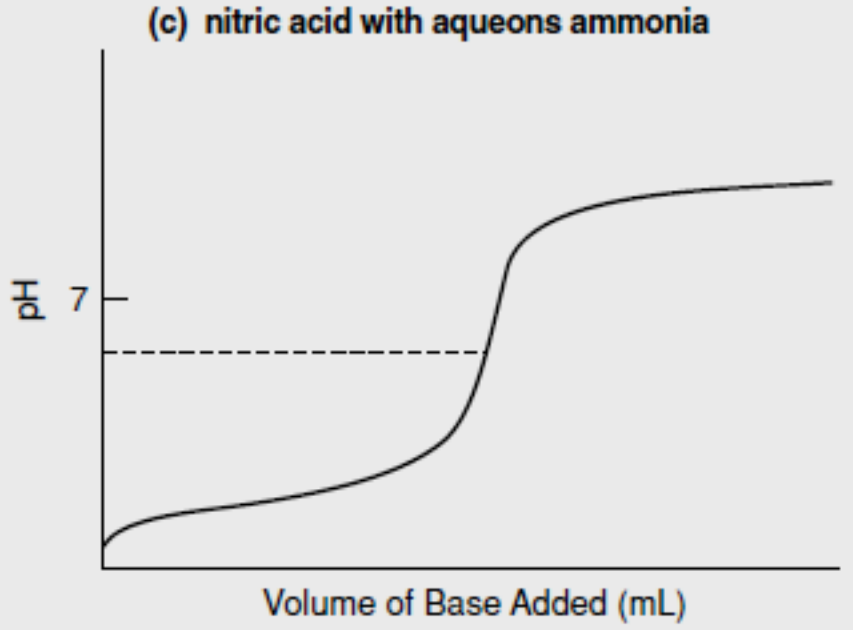
45.

(a) nitric acid with potassium hydroxide



(b) ethanoic acid with potassium hydroxide





46. A polyprotic acid will have two or more steep changes in pH corresponding to the number of protons the acid donates.

47. **(a)** The solution contained a weak acid based on the shape of the titration curve.

(b) The pH at equivalence was approximately 9.

(c) Yes, the solution acted as a buffer from pH 4 to pH 6.

(d) Phenolphthalein would be an appropriate indicator, since its endpoint is between pH 8.2 and pH 10.0.

(e) The solution is most likely ii, $CH_3COOH(aq)$, since this is the only weak acid in the list.

48. OMITTED FROM STUDENT TEXT

Answers to Making Connections Questions

49. The acidic rainwater might be caused by a number of factors, including a nearby coal-burning electric generating plant, a gas-processing facility, or even being downwind from a source of acidic emissions from far away. Students should outline the data to be collected,

such as the pH of rain or snow, the date of the precipitation, and the wind direction and strength.

50. (a) Hydroxyapatite, is a weak base due to its hydroxy groups.

(b) $Ca_{10}(PO_4)_6(OH)_2(s) + 8H_3O^+(aq) \rightleftharpoons 6CaHPO_4(s) + 10H_2O(\ell) + 4Ca^{2+}(aq)$

(c) Bacteria in the mouth feed off the sugars in candy. The bacteria excrete acids and, as the equation shows, acids react with $CaHPO_4$ which causes teeth to decay.

51. ICE Table

concentration (mol/L)

$$NH_2(CH_2)_4NH_2(aq) + H_2O(\ell) \rightleftharpoons OH^-(aq) + NH_2(CH_2)_4NH_3^+(aq)$$

Initial	0.10		≈ 0	0
Change	-2.1×10^{-3}		$+2.1 \times 10^{-3}$	$+2.1 \times 10^{-3}$
Equilibrium	$0.10 - 2.1 \times 10^{-3} = 0.098$		2.1×10^{-3}	2.1×10^{-3}

$$K_b = \frac{[NH_2(CH_2)_4NH_3^+(aq)][OH^-(aq)]}{[NH_2(CH_2)_4NH_2(aq)]}$$

$$= \frac{(2.1 \times 10^{-3})(2.1 \times 10^{-3})}{0.098}$$

$$K_b = 4.5 \times 10^{-5}$$

52. (a) $H_3VO_4(aq) + H_2O(\ell) \rightleftharpoons H_2VO_4^-(aq) + H_3O^+(aq)$

$H_2VO_4^-(aq) + H_2O(\ell) \rightleftharpoons HVO_4^{2-}(aq) + H_3O^+(aq)$

$HVO_4^{2-}(aq) + H_2O(\ell) \rightleftharpoons VO_4^{3-}(aq) + H_3O^+(aq)$

(b) As an acid:

$H_2VO_4^-(aq) + H_2O(\ell) \rightleftharpoons HVO_4^{2-}(aq) + H_3O^+(aq)$

As a base:

$$H_2VO_4^-(aq) + H_2O(\ell) \rightleftharpoons H_3VO_4(aq) + OH^-(aq)$$

(c) The stronger acid is $H_3VO_4(aq)$. In a polyprotic acid, acid strength always decreases as each proton is removed, because the next proton must be removed from an increasingly negatively charged ion.

53. The ammonium ion acts as an acid. From the Appendix, K_a for $NH_4^+(aq)$ is 5.6×10^{-10}. The hydrogen carbonate ion acts as a base. From the Appendix, K_a for $HCO_3^-(aq)$ is 4.7×10^{-11}.

$$K_b = \frac{K_w}{K_a} = \frac{1.0 \times 10^{-14}}{4.7 \times 10^{-11}} = 2.1 \times 10^{-4}$$

Because K_b for $HCO_3^-(aq)$ is greater than K_a for $NH_4^+(aq)$, a solution of $NH_4HCO_3(aq)$ will be slightly basic.